UNITED STATES PATENT APPLICATION FOR

ELECTRO-KINETIC AIR TRANSPORTER AND CONDITIONER DEVICE WITH ENHANCED ANTI-MICROORGANISM CAPABILITY

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<u>Claim of Priority:</u>

[0001] This application claims priority from provisional application entitled "ELECTRO-KINETIC AIR TRANSPORTER AND CONDITIONER DEVICE WITH ENHANCED ANTI-MICROORGANISM CAPABILITY," Application No. 60/341,179, filed December 13, 2001 under 35 U.S.C. 119(e),which application is incorporated herein by reference. This application claims priority from provisional application entitled "FOCUS ELECTRODE, ELECTRO-KINETIC AIR TRANSPORTER-CONDITIONER DEVICES," Application No. 60/306,479, filed July 18, 2001 under 35 U.S.C. 119(e),which application is incorporated herein by reference. This application claims priority from and is a continuation-in-part of patent application "ELECTRO-KINETIC DEVICE WITH ENHANCED ANTI-MICROORGANISM CAPABILITY", Application No. 09/774,198, filed January 29, 2001, and incorporated herein by reference. This application claims priority from and is a continuation-in-part of U.S. Patent Application No. 09/924,624 filed August 8, 2001 which is a continuation of U.S. Patent No. 09/564,960 filed May 4, 2000, which is a continuation-in-part of U.S. Patent Application No. 09/186,471 filed November 5, 1998, now U.S. Patent No. 6,176,977. All of the above are incorporated herein by reference.

Cross-Reference to Related Applications:

[0002] 1. U.S. Patent Application No. 60/341,518, filed December 13, 2001, entitled "ELECTRO-KINETIC AIR TRANSPORTER-CONDITIONER DEVICES WITH AN UPSTREAM FOCUS ELECTRODE"; SHPR-01041US6

[0003] 2. U.S. Patent Application No. 60/341,090, filed December 13, 2001, entitled "ELECTRO-KINETIC AIR TRANSPORTER-CONDITIONER DEVICES WITH TRAILING ELECTRODE"; SHPR-01041USE

[0004] 3. U.S. Patent Application No. 60/341,433, filed December 13, 2001, entitled "ELECTRO-KINETIC AIR TRANSPORTER-CONDITIONER DEVICES WITH INTERSTITIAL ELECTRODE"; SHPR-01041USF

[0005] 4. U.S. Patent Application No. 60/341,592, filed December 13, 2001, entitled "ELECTRO-KINETIC AIR TRANSPORTER-CONDITIONER DEVICES WITH ENHANCED COLLECTOR ELECTRODE"; SHPR-01041USG

[0006] 5. U.S. Patent Application No. 60/341,320, filed December 13, 2001, entitled "ELECTRO-KINETIC AIR TRANSPORTER-CONDITIONER DEVICES WITH ENHANCED EMITTER ELECTRODE"; SHPR-01041USH

[0007] 6. U.S. Patent Application No. 60/340,702, filed December 13, 2001, entitled "ELECTRO-KINETIC AIR TRANSPORTER AND CONDITIONER DEVICE WITH ENHANCED HOUSING CONFIGURATION AND ENHANCED ANTI-MICROORGANISM CAPABILITY"; SHPR-01028US2

[0008] 7. U.S. Patent Application No. 60/341,377, filed December 13, 2001, entitled "ELECTRO-KINETIC AIR TRANSPORTER AND CONDITIONER DEVICE WITH ENHANCED MAINTENANCE FEATURES AND ENHANCED ANTI-MICROORGANISM CAPABILITY"; SHPR-01028US3

[0009] 8. U.S. Patent Application No.10/023,197, filed December 13, 2001, entitled "ELECTRO-KINETIC AIR TRANSPORTER-CONDITIONER WITH ENHANCED CLEANING FEATURES"; SHPR-01041USI

[0010] 9. U.S. Patent Application No. 10/023,460, filed December 13, 2001, entitled "ELECTRO-KINETIC AIR TRANSPORTER CONDITIONER WITH PIN-RING CONFIGURATION"; SHPR-01041USJ

[0011] 10. U.S. Patent Application No. 60/341,176, filed December 13, 2001, entitled "ELECTRO-KINETIC AIR TRANSPORTER-CONDITIONER WITH NON-EQUIDISTANT COLLECTOR ELECTRODES "; SHPR-01041US8

[0012] 11. U.S. Patent Application No. 60/340,288, filed December 13, 2001, entitled "DUAL INPUT AND OUTLET ELECTROSTATIC AIR TRANSPORTER-CONDITIONER"; SHPR-01041US7

[0013] 12. U.S. Patent Application No. 60340,462, filed December 13, 2001, entitled "ELECTRO-KINETIC AIR TRANSPORTER-CONDITIONER DEVICES WITH A ENHANCED COLLECTOR ELECTRODE FOR COLLECTION OF MORE PARTICULATE MATTER"; SHPR-01041US9

[0014] 13. U.S. Patent Application No. 10/xxx,xxx, filed herewith, entitled "ELECTRO-KINETIC AIR TRANSPORTER-CONDITIONER DEVICES WITH AN UPSTREAM FOCUS ELECTRODE"; SHPR-01041USL

[0015] 14. U.S. Patent Application No. 10/xxx,xxx, filed herewith, entitled "ELECTRO-KINETIC AIR TRANSPORTER-CONDITIONER DEVICES WITH TRAILING ELECTRODE"; SHPR-01041USM

[0016] 15. U.S. Patent Application No. 10/xxx,xxx, filed herewith, , entitled "ELECTRO-KINETIC AIR TRANSPORTER-CONDITIONER DEVICES WITH INTERSTITIAL ELECTRODE"; SHPR-01041USN

[0017] 16. U.S. Patent Application No. 10/xxx,xxx, filed herewith, entitled "ELECTRO-KINETIC AIR TRANSPORTER-CONDITIONER DEVICES WITH ENHANCED COLLECTOR ELECTRODE"; SHPR-01041USO

[0018] 17. U.S. Patent Application No. 10/xxx,xxx, filed herewith, entitled "ELECTRO-KINETIC AIR TRANSPORTER-CONDITIONER DEVICES WITH ENHANCED EMITTER

ELECTRODE"; SHPR-01041USP

[0019] 18. U.S. Patent Application No. 10/xxx,xxx, filed herewith, entitled "ELECTRO-KINETIC AIR TRANSPORTER AND CONDITIONER DEVICE WITH ENHANCED HOUSING CONFIGURATION AND ENHANCED ANTI-MICROORGANISM CAPABILITY"; SHPR-01028US5

[0020] 19. U.S. Patent Application No. 10/xxx,xxx, filed herewith, entitled "ELECTRO-KINETIC AIR TRANSPORTER AND CONDITIONER DEVICE WITH ENHANCED MAINTENANCE FEATURES AND ENHANCED ANTI-MICROORGANISM CAPABILITY"; SHPR-01028US6

[0021] 20. U.S. Patent Application No. 10/xxx,xxx, filed herewith, entitled "ELECTRO-KINETIC AIR TRANSPORTER-CONDITIONER WITH NON-EQUIDISTANT COLLECTOR ELECTRODES "; SHPR-01041USQ

[0022] 21. U.S. Patent Application No. 10/xxx,xxx, filed herewith, entitled "DUAL INPUT AND OUTLET ELECTROSTATIC AIR TRANSPORTER-CONDITIONER"; SHPR-01041USR and

[0023] 22. U.S. Patent Application No. 10/xxx,xxx, filed herewith, entitled "ELECTRO-KINETIC AIR TRANSPORTER-CONDITIONER DEVICES WITH A ENHANCED COLLECTOR ELECTRODE FOR COLLECTION OF MORE PARTICULATE MATTER". SHPR-01041USS

[0024] All of the above are incorporated herein by reference.

Field of the Invention:

[0025] The present invention relates generally to a device that transports and conditions air. More specifically, an embodiment of the present invention provides such a device with the enhanced ability to reduce the number of microorganisms within the air, which microorganisms can include germs, bacteria, and viruses.

Background of the Invention:

[0026] U.S. Patent No. 4,789,801 issued to Lee, and incorporated herein by reference, describes various devices to generate a stream of ionized air using an electro-kinetic technique. In overview, electro-kinetic techniques use high electric fields to ionize air molecules, a process that produces ozone (O_3) as a byproduct. Ozone is an unstable molecule of oxygen that is commonly produced as a byproduct of high voltage arcing. In appropriate concentrations, ozone can be a desirable and useful substance. But ozone by itself may not be effective to kill microorganisms such as germs, bacteria, and viruses in the environment surrounding the device.

[0027] Fig. 1 depicts a generic electro-kinetic device **10** to condition air. Device **10** includes a housing **20** that typically has at least one air input **30** and at least one air output **40**. Within housing **20** there is disposed an electrode assembly or system **50** comprising a first electrode array **60** having at least one electrode **70** and comprising a second electrode array **80** having at least one electrode **90**. System **10** further includes a high voltage generator **95** coupled between the first and second electrode arrays. As a result, ozone and ionized particles of air are generated within device **10**, and there is an electro-kinetic flow of air in the direction from the first electrode array **60** towards the second electrode array **80**. In Fig. 1, the large arrow denoted IN represents ambient air that can enter input port **30**. The small "x"'s denote particulate matter that may be present in the incoming ambient air. The air movement is in the direction of the large arrows, and the output airflow, denoted OUT, exits device **10** via outlet **40**. An advantage of electro-kinetic devices such as device **10** is that an airflow is created without using fans or other moving parts. Thus, device **10** in Fig. 1 can function somewhat as a fan to create an output airflow, but without requiring moving parts.

[0028] Preferably particulate matter "x" in the ambient air can be electrostatically attracted to the second electrode array **80**, with the result that the outflow (OUT) of air from device **10** not only contains ozone and ionized air, but can be cleaner than the ambient air. In such devices, it can become necessary to occasionally clean the second electrode array electrodes **80** to remove particulate matter and other debris from the surface of electrodes **90**. Accordingly, the outflow

of air (OUT) is conditioned in that particulate matter is removed and the outflow includes appropriate amounts of ozone, and some ions.

[0029] An outflow of air containing ions and ozone may not, however, destroy or significantly reduce microorganisms such as germs, bacteria, fungi, viruses, and the like, collectively hereinafter "microorganisms." It is known in the art to destroy such microorganisms with, by way of example only, germicidal lamps. Such lamps can emit ultra- violet radiation having a wavelength of about 254 nm. For example, devices to condition air using mechanical fans, HEPA filters, and germicidal lamps are sold commercially by companies such as Austin Air, C.A.R.E. 2000, Amaircare, and others. Often these devices are somewhat cumbersome, and have the size and bulk of a small filing cabinet. Although such fan-powered devices can reduce or destroy microorganisms, the devices tend to be bulky, and are not necessarily silent in operation.

[0030] U.S. Patent Nos. 5,879,435, 6,019,815, and 6,149,717, issued to Satyapal et al., and incorporated herein by reference, discloses an electronic air cleaner that contains an electrostatic precipitator cell and a germicidal lamp for use, among other uses, with a forced air furnace system. The electrostatic precipitator cell includes multiple collector plates for collecting particulate material from the airstream. The germicidal lamp is disposed within the air cleaner to irradiate the collector plates and to destroy microbial growth that might occur on the particulate material deposited on the collector plates. Particles that pass through the air cleaner due to the action of the fan of the forced air furnace, and that are not deposited on the collector plates, generally are not subjected to the germicidal radiation for a period of time long enough for the light to substantially reduce microorganisms within the airflow.

[0031] What is needed is a device to condition air in a room that can operate relatively silently to remove particulate matter in the air, that can preferably output appropriate amounts of ozone or no ozone, and that can kill or reduce microorganisms such as germs, fungi, bacteria, viruses, and the like contained within the airflow.

Summary of the Present Invention:

[0032] Embodiments of the present invention provide devices that fulfill the above described needs. It is an aspect of the present invention to reduce the amount of microorganisms within the airflow. An embodiment of the present invention has an ion generator to create an airflow and collect particulates, and a germicidal lamp to kill microorganisms. The housing is shaped to slow the airflow rate as the airflow passes the germicidal lamp, allowing a longer dwell time of the air in front of the germicidal lamp.

[0033] An aspect of the invention includes the germicidal lamp located upstream of the ion generator. An embodiment of the invention locates the germicidal lamp within the housing to maximize the amount of air irradiated, and to minimize the disturbance the lamp housing will cause to the airflow rate of the device. Another embodiment maximizes the amount of germicidal light that will directly shine on the airflow, without having to be reflected.

[0034] Another aspect of the present invention ensures that there is no direct line- of-sight through the air inlet or the air outlet of the housing to the germicidal lamp. An embodiment of the present invention has vertical fins covering the air inlet and air outlet to prohibit an individual from directly staring at the germicidal radiation emitted by the lamp. Another embodiment includes a shell or lamp housing that substantially surrounds the germicidal lamp to direct the radiation away from the air inlet, and the air outlet.

[0035] Another feature of an embodiment of the invention includes the ease of removeability of electrodes from the ion generator and ease of replacement of the germicidal lamp. An embodiment of the invention includes a rear panel that can be removed to expose the germicidal lamp for replacing. Another embodiment of the invention has second electrodes and a germicidal lamp that can be removed through the top of the housing for cleaning and/or replacement.

[0036] Other features and advantages of the invention will appear from the following description in which the preferred embodiments have been set forth in detail, in conjunction with the accompanying drawings and claims.

Brief Description of the Figures:

[0037] FIG. 1 depicts a generic electro-kinetic conditioner device that outputs ionized air and ozone, according to the prior art;

[0038] FIGS. 2A-2B; Fig. 2A is a perspective view of an embodiment of the housing for the present invention; Fig. 2B is a perspective view of the embodiment shown in Fig. 2A, illustrating the removable array of second electrodes;

[0039] FIGS. 3A-3E; Fig. 3A is a perspective view of an embodiment of the present invention without a base; Fig. 3B is a top view of the embodiment of the present invention illustrated in Fig. 3A; Fig. 3C is a partial perspective view of the embodiment shown in Figs. 3A-3B, illustrating the removable second array of electrodes; Fig. 3D is a side view of the embodiment of the present invention of Fig. 3A including a base; Fig. 3E is a perspective view of the embodiment in Fig. 3D, illustrating a removable rear panel which exposes a germicidal lamp;

[0040] FIG. 4 is a perspective view of another embodiment of the present invention;

[0041] FIGS. 5A-5B; Fig. 5A is a top, partial cross-sectioned view of an embodiment of the present invention, illustrating one configuration of the germicidal lamp; Fig. 5B is a top, partial cross-sectioned view of another embodiment of the present invention, illustrating another configuration of the germicidal lamp;

[0042] FIG. 6 is a top, partial cross-sectional view of yet another embodiment of the present invention;

[0043] FIGS. 7A-7B; Fig. 7A is a partial electrical block diagram of an embodiment of the circuit of the present invention; Fig. 7B is a partial electrical block diagram of the embodiment of the present invention for use with the circuit depicted in Fig. 7A;

[0044] FIGS. 8A-8F; Fig. 8A is a perspective view showing an embodiment of an electrode assembly, according to the present invention; Fig. 8B is a plan view of the embodiment illustrated in Fig. 8A; Fig. 8C is a perspective view showing another embodiment of an electrode assembly, according to the present invention; Fig. 8D is a plan view illustrating a modified version of the embodiment shown in Fig. 8C; Fig. 8E is a perspective view showing yet another

embodiment of an electrode assembly according to the present invention; Fig. 8F is a plan view of the embodiment shown in Fig. 8E;

[0045] FIGS. 9A-9B; Fig. 9A is a perspective view of still another embodiment of the present invention; Fig. 9B is a plan view of a modified embodiment of that shown in FIG.. 9A;

[0046] FIGS. 10A-10D; Fig. 10A is a perspective view of another embodiment of the present invention; Fig. 10B is a perspective view of a modified embodiment of that shown in Fig. 10A; Fig. 10C is a perspective view of a modified embodiment of that shown in FIG.. 10B; Fig. 10D is a modified embodiment of that shown in Fig. 8D;

[0047] FIGS. 11A-11C; Fig. 11A is a perspective view of yet another embodiment of the present invention; Fig. 11B is a perspective view of a modified embodiment of that shown in Fig. 11A; Fig. 11C is a perspective view of a modified embodiment of that shown in FIG.. 11B;

[0048] FIGS. 12A-12C; Fig. 12A is a perspective view of still another embodiment of the present invention; Fig. 12B is a perspective view of a modified embodiment of that shown in Fig. 9A; Fig. 12C is a perspective view of a modified embodiment of that shown in Fig. 12A;

[0049] FIGS. 13A-13C; Fig. 13A is a perspective view of another embodiment of the present invention; Fig. 13B is a plan view of the embodiment shown in Fig. 13A; Fig. 13C is a plan view of still another embodiment of the present invention;

[0050] FIGS. 14A-14F; Fig. 14A is a plan view of still another embodiment of the present invention; Fig. 14B is a plan view of a modified embodiment of that shown in Fig. 14A; Fig. 14C is a plan view of yet another embodiment of the present invention; Fig. 14D is a plan view of a modified embodiment of that shown in Fig. 14C; Fig. 14E is a plan view of another embodiment of the present invention; Fig. 14F is a plan view of a modified embodiment of that shown in Fig. 14E; and

[0051] FIGS. 15A-15C; Fig. 15A is perspective view of another embodiment of the present invention; Fig. 15B is a perspective view of still another embodiment of the present invention; Fig. 15C is a perspective view of yet another embodiment of the present invention.

Detailed Description of the Preferred Embodiment:

Overall Air Transporter-Conditioner System Configuration:

Figs. 2A-2B

[0052] Figs. 2A-2B depicts a system which does not have incorporated therein a germicidal lamp. However, these embodiments do include other aspects such as the removable second electrodes which can be included in the other described embodiments.

[0053] Figs. 2A and 2B depict an electro-kinetic air transporter-conditioner system **100** whose housing **102** includes preferably rear-located intake vents or louvers **104** and preferably front located exhaust vents **106**, and a base pedestal **108**. Preferably, the housing **102** is free standing and/or upstandingly vertical and/or elongated. Internal to the transporter housing **102** is an ion generating unit **160**, preferably powered by an AC:DC power supply that is energizable or excitable using switch **S1**. Switch **S1**, along with the other below described user operated switches, are conveniently located at the top **103** of the unit **100**. Ion generating unit **160** is self-contained in that other ambient air, nothing is required from beyond the transporter housing **102**, save external operating potential, for operation of the present invention.

[0054] The upper surface **103** of the housing **102** includes a user-liftable handle member **112** to which is affixed a second array **240** of collector electrodes **242**. The housing **102** also encloses a first array of emitter electrodes **230**, or a single first emitter electrode shown here as a single wire or wire-shaped electrode **232**. (The terms "wire" and "wire-shaped" shall be used interchangeably herein to mean an electrode either made from a wire or, if thicker or stiffer than a wire, having the appearance of a wire.) In the embodiment shown, handle member **112** lifts second array electrodes **240** upward causing the second electrode to telescope out of the top of the housing and, if desired, out of unit **100** for cleaning, while the first electrode array **230** remains within unit **100**. As is evident from the figure, the second array of electrodes **240** can be lifted vertically out from the top **103** of unit **100** along the longitudinal axis or direction of the elongated housing **102**. This arrangement with the second electrodes removable from the top **103** of the unit **100**, makes it easy for the user to pull the second electrodes **242** out for cleaning. In Fig. 2B, the

bottom ends of second electrodes **242** are connected to a member **113**, to which is attached a mechanism **500**, which includes a flexible member and a slot for capturing and cleaning the first electrode **232**, whenever handle member **112** is moved upward or downward by a user. The first and second arrays of electrodes are coupled to the output terminals of ion generating unit **160**.

[0055] The general shape of the embodiment of the invention shown in Figs. 2A and 2B is that of a figure eight in cross-section, although other shapes are within the spirit and scope of the invention. The top-to-bottom height in one preferred embodiment is, 1 m, with a left-to-right width of preferably 15 cm, and a front-to-back depth of perhaps 10 cm, although other dimensions and shapes can of course be used. A louvered construction provides ample inlet and outlet venting in an ergonomical housing configuration. There need be no real distinction between vents **104** and **106**, except their location relative to the second electrodes. These vents serve to ensure that an adequate flow of ambient air can be drawn into or made available to the unit **100**, and that an adequate flow of ionized air that includes appropriate amounts of O_3 flows out from unit **100**.

[0056] As will be described, when unit **100** is energized by depressing switch **S1**, high voltage or high potential output by an ion generator **160** produces ions at the first electrode **232**, which ions are attracted to the second electrodes **242**. The movement of the ions in an "IN" to "OUT" direction carries with the ions air molecules, thus electro-kinetically producing an outflow of ionized air. The "IN" rotation in Figs. 2A and 2B denote the intake of ambient air with particulate matter **60**. The "OUT" notation in the figures denotes the outflow of cleaned air substantially devoid of the particulate matter, which particulates matter adheres electrostatically to the surface of the second electrodes. In the process of generating the ionized airflow appropriate amounts of ozone (O_3) are beneficially produced. It may be desired to provide the inner surface of housing **102** with an electrostatic shield to reduce detectable electromagnetic radiation. For example, a metal shield could be disposed within the housing, or portions of the interior of the housing can be coated with a metallic paint to reduce such radiation.

Preferred Embodiments of Air-Transporter-Conditioner System with Germicidal Lamp

[0057] Figs. 3A-6 depict various embodiments of the device **200**, with an improved ability to diminish or destroy microorganisms including bacteria, germs, and viruses. Specifically, Figs. 3A-6 illustrate various preferred embodiments of the elongated and upstanding housing **210** with the operating controls located on the top surface **217** of the housing **210** for controlling the device **200**.

Figs. 3A-3E

[0058] Fig. 3A illustrates a first preferred embodiment of the housing **210** of device **200**. The housing **210** is preferably made from a lightweight inexpensive material, ABS plastic for example. As a germicidal lamp (described hereinafter) is located within the housing **210**, the material must be able to withstand prolonged exposure to class UV-C light. Non "hardened" material will degenerate over time if exposed to light such as UV-C. By way of example only, the housing **210** may be manufactured from CYCLOLAC® ABS Resin, (material designation VW300(f2)) which is manufactured by General Electric Plastics Global Products, and is certified by UL Inc. for use with ultraviolet light. It is within the scope of the present invention to manufacture the housing **210** from other UV appropriate materials.

[0059] In a preferred embodiment, the housing **210** is aerodynamically oval, elliptical, teardrop-shaped or egg-shaped. The housing **210** includes at least one air intake **250**, and at least one air outlet **260**. As used herein, it will be understood that the intake **250** is "upstream" relative to the outlet **260**, and that the outlet **260** is "downstream" from the intake **250**. "Upstream" and "downstream" describe the general flow of air into, through, and out of device **200**, as indicated by the large hollow arrows.

[0060] Covering the inlet **250** and the outlet **260** are fins, louvers, or baffles **212**. The fins **212** are preferably elongated and upstanding, and thus in the preferred embodiment, vertically oriented to minimize resistance to the airflow entering and exiting the device **200**. Preferably the fins **212** are vertical and parallel to at least the second collector electrode array **240** (see Fig. 5A).

The fins **212** can also be parallel to the first emitter electrode array **230**. This configuration assists in the flow of air through the device **200** and also assists in preventing UV radiation from the UV or germicidal lamp **290** (described hereinafter), or other germicidal source, from exiting the housing **210**. By way of example only, if the long width of the body from the inlet **250** to the outlet **260** is 8 inches, the collector electrode **242** (see Fig. 5A) can be 1 ¼" wide in the direction of airflow, and the fins **212** can be ¾" or ½" wide in the direction airflow. Of course, other proportionate dimensions are within the spirit and scope of the invention. Further, other fin and housing shapes which may not be as aerodynamic are within the spirit and scope of the invention.

[0061] From the above it is evident that preferably the cross-section of the housing **210** is oval, elliptical, teardrop-shaped or egg shaped with the inlet **250** and outlet **260** narrower than the middle (see line A-A in Fig. 5A) of the housing **210**. Accordingly, the airflow, as it passes across line A-A, is slower due to the increased width and area of the housing **210**. Any bacteria, germs, or virus within the airflow will have a greater dwell time and be neutralized by a germicidal device, such as, preferably, an ultraviolet lamp.

[0062] Fig. 3B illustrates the operating controls for the device **200**. Located on top surface **217** of the housing **210** is an airflow speed control dial **214**, a boost button **216,** a function dial **218**, and an overload/cleaning light **219**. The airflow speed control dial **214** has three settings from which a user can choose: LOW, MED, and HIGH. The airflow rate is proportional to the voltage differential between the electrodes or electrode arrays coupled to the ion generator **160**. The LOW, MED, and HIGH settings generate a different predetermined voltage difference between the first and second arrays. For example, the LOW setting will create the smallest voltage difference, while the HIGH setting will create the largest voltage difference. Thus, the LOW setting will cause the device **200** to generate the slowest airflow rate, while the HIGH setting will cause the device **200** to generate the fastest airflow rate. These airflow rates are created by the electronic circuit disclosed in Figs. 7A-7B, and operate as disclosed below.

[0063] The function dial **218** enables a user to select "ON," "ON/GP," or "OFF." The

unit **200** functions as an electrostatic air transporter-conditioner, creating an airflow from the inlet **250** to the outlet **260**, and removing the particles within the airflow when the function dial **218** is set to the "ON" setting. The germicidal lamp **290** does not operate, or emit UV light, when the function dial **218** is set to "ON." The device **200** also functions as an electrostatic air transporter-conditioner, creating an airflow from the inlet **250** to the outlet **260**, and removing particles within the airflow when the function dial **218** is set to the "ON/GP" setting. In addition, the "ON/GP" setting activates the germicidal lamp **290** to emit UV light to remove or kill bacteria within the airflow. The device **200** will not operate when the function dial **218** is set to the "OFF" setting.

[0064] As previously mentioned, the device **200** preferably generates small amounts of ozone to reduce odors within the room. If there is an extremely pungent odor within the room, or a user would like to temporarily accelerate the rate of cleaning, the device **200** has a boost button **216**. When the boost button **216** is depressed, the device **200** will temporarily increase the airflow rate to a predetermined maximum rate, and generate an increased amount of ozone. The increased amount of ozone will reduce the odor in the room faster than if the device **200** was set to HIGH. The maximum airflow rate will also increase the particle capture rate of the device **200**. In a preferred embodiment, pressing the boost button **216** will increase the airflow rate and ozone production continuously for 5 minutes. This time period may be longer or shorter. At the end of the preset time period (e.g., 5 minutes), the device **200** will return to the airflow rate previously selected by the control dial **214**.

[0065] The overload/cleaning light **219** indicates if the second electrodes **242** require cleaning, or if arcing occurs between the first and second electrode arrays. The overload/cleaning light **219** may illuminate either amber or red in color. The light **219** will turn amber if the device **200** has been operating continuously for more than two weeks and the second array **240** has not been removed for cleaning within the two week period. The amber light is controlled by the below described 2-week time circuit **130** (see Fig. 7B) which is connected to the power setting circuit **122**. The device **200** will continue to operate after the light **219** turns amber. The light **219** is only an indicator. There are two ways to reset or turn the light **219** off. A user may remove and

replace the second array **240** from the unit **200**. The user may also turn the control dial **218** to the OFF position, and subsequently turn the control dial **218** back to the "ON" or "ON/GP" position. The timer circuit **130** will reset and begin counting a new two week period upon completing either of these two steps.

[0066] The light **219** will turn red to indicate that arcing has occurred between the first array **230** and the second array **240**, as sensed by a sensing circuit **132**, which is connected between the IGBT switch **126** and the connector oscillator **124** of Fig. 7B (as described below). When arcing occurs, the device **200** will automatically shut itself off. The device **200** cannot be restarted until the device **200** is reset. To reset the device **200**, the second array **240** should first be removed from the housing **210** after the unit **200** is turned off. The second electrode **240** can then be cleaned and placed back into the housing **210**. Then, the device **200** is turned on. If no arcing occurs, the device **200** will operate and generate an airflow. If the arcing between the electrodes continues, the device **200** will again shut itself off, and need to be reset.

[0067] Fig. 3C illustrates the second electrodes **242** partially removed from the housing **210**. In this embodiment, the handle **202** is attached to an electrode mounting bracket **203**. The bracket **203** secures the second electrodes **242** in a fixed, parallel configuration. Another similar bracket **203** is attached to the second electrodes **242** substantially at the bottom (not shown). The two brackets **203** align the second electrodes **242** parallel to each other, and in-line with the airflow traveling through the housing **210**. Preferably, the brackets **203** are non-conductive surfaces.

[0068] One of the various safety features can be seen with the second electrodes **242** partially removed. As shown in Fig. 3C, an interlock post **204** extends from the bottom of the handle **202**. When the second electrodes **242** are placed completely into the housing **210**, the handle **202** rests within the top surface **217** of the housing, as shown by Figs. 3A-3B. In this position, the interlock post **204** protrudes into the interlock recess **206** and activates a switch connecting the electrical circuit of the unit **200**. When the handle **202** is removed from the housing **210**, the interlock post **204** is pulled out of the interlock recess **206** and the switch opens the

electrical circuit. With the switch in an open position, the unit **200** will not operate. Thus, if the second electrodes **242** are removed from the housing **210** while the unit **200** is operating, the unit **200** will shut off as soon as the interlock post **204** is removed from the interlock recess **206**.

[0069] Fig. 3D depicts the housing **210** mounted on a stand or base **215**. The housing **210** has an inlet **250** and an outlet **260**. The base **215** sits on a floor surface. The base **215** allows the housing **210** to remain in a vertical position. It is within the scope of the present invention for the housing **210** to be pivotally connected to the base **215**. As can be seen in Fig. 3D, housing **210** includes sloped top surface **217** and sloped bottom surface **213**. These surfaces slope inwardly from inlet **250** to outlet **260** to additionally provide a streamline appearance and effect.

[0070] Fig. 3E illustrates that the housing **210** has a removable rear panel **224**, allowing a user to easily access and remove the germicidal lamp **290** from the housing **210** when the lamp **290** expires. This rear panel **224** in this embodiment defines the air inlet and comprises the vertical louvers. The rear panel **224** has locking tabs **226** located on each side, along the entire length of the panel **224**. The locking tabs **226**, as shown in Fig. 3E, are "L"-shaped. Each tab **224** extends away from the panel **224**, inward towards the housing **210**, and then projects downward, parallel with the edge of the panel **224**. It is within the spirit and scope of the invention to have differently shaped tabs **226**. Each tab **224** individually and slidably interlocks with recesses **228** formed within the housing **210**. The rear panel **224** also has a biased lever (not shown) located at the bottom of the panel **224** that interlocks with the recess **230**. To remove the panel **224** from the housing **210**, the lever is urged away from the housing **210**, and the panel **224** is slid vertically upward until the tabs **226** disengage the recesses **228**. The panel **224** is then pulled away from the housing **210**. Removing the panel **224** exposes the lamp **290** for replacement.

[0071] The panel **224** also has a safety mechanism to shut the device **200** off when the panel **224** is removed. The panel **224** has a rear projecting tab (not shown) that engages the safety interlock recess **227** when the panel **224** is secured to the housing **210**. By way of example only, the rear tab depresses a safety switch located within the recess **227** when the rear panel **224** is secured to the housing **210**. The device **200** will operate only when the rear tab in the panel **224**

is fully inserted into the safety interlock recess **227**. When the panel **224** is removed from the housing **210**, the rear projecting tab is removed from the recess **227** and the power is cut-off to the entire device **200**. For example if a user removes the rear panel **224** while the device **200** is running, and the germicidal lamp **290** is emitting UV radiation, the device **200** will turn off as soon as the rear projecting tab disengages from the recess **227**. Preferably, the device **200** will turn off when the rear panel **224** is removed only a very short distance (e.g., ¼") from the housing **210**. This safety switch operates very similar to the interlocking post **204**, as shown in Fig. 3C.

Fig.4

[0072] Fig. 4 illustrates yet another embodiment of the housing **210**. In this embodiment, the germicidal lamp **290** may be removed from the housing **210** by lifting the germicidal lamp **290** out of the housing **210** through the top surface **217**. The housing **210** does not have a removable rear panel **224**. Instead, a handle **275** is affixed to the germicidal lamp **290**. The handle **275** is recessed within the top surface **217** of the housing **210** similar to the handle **202**, when the lamp **290** is within the housing **210**. To remove the lamp **290**, the handle **275** is vertically raised out of the housing **210**.

[0073] The lamp **290** is situated within the housing **210** in a similar manner as the second array of electrodes **240**. That is to say, that when the lamp **290** is pulled vertically out of the top **217** of the housing **210**, the electrical circuit that provides power to the lamp **290** is disconnected. The lamp **290** is mounted in a lamp fixture that has circuit contacts which engages the circuit in Fig. 7A. As the lamp **290** and fixture are pulled out, the circuit contacts are disengaged. Further, as the handle **275** is lifted from the housing **210**, a cutoff switch will shut the entire device **200** off. This safety mechanism ensures that the device **200** will not operate without the lamp **290** placed securely in the housing **210**, preventing an individual from directly viewing the radiation emitted from the lamp **290**. Reinserting the lamp **290** into the housing **210** causes the lamp fixture to re-engage the circuit contacts as is known in the art. In similar, but less convenient fashion, the lamp **290** may be designed to be removed from the bottom of the housing **210**.

[0074] The germicidal lamp **290** is a preferably UV-C lamp that preferably emits viewable light and radiation (in combination referred to as radiation or light **280**) having wavelength of about 254 nm. This wavelength is effective in diminishing or destroying bacteria, germs, and viruses to which it is exposed. Lamps **290** are commercially available. For example, the lamp **290** may be a Phillips model TUV 15W/G15 T8, a 15 W tubular lamp measuring about 25 mm in diameter by about 43 cm in length. Another suitable lamp is the Phillips TUV 8WG8 T6, an 8 W lamp measuring about 15 mm in diameter by about 29 cm in length. Other lamps that emit the desired wavelength can instead be used.

<u>Figs. 5A-5B</u>

[0075] As previously mentioned, one role of the housing **210** is to prevent an individual from viewing, by way of example, ultraviolet (UV) radiation generated by a germicidal lamp **290** disposed within the housing **210**. Figs. 5A-5B illustrate preferred locations of the germicidal lamp **290** within the housing **210**. Figs. 5A-5B further show the spacial relationship between the germicidal lamp **290** and the electrode assembly **220**, and the germicidal lamp **290** and the inlet **250** and the outlet **260** and the inlet and outlet louvers.[0076] In a preferred embodiment, the inner surface **211** of the housing **210** diffuses or absorbs the UV light emitted from the lamp **290**. Figs. 5A-5B illustrate that the lamp **290** does emit some light **280** directly onto the inner surface **211** of the housing **210**. By way of example only, the inner surface **211** of the housing **210** can be formed with a non-smooth finish, or a non-light reflecting finish or color, to also prevent the UV-C radiation from exiting through either the inlet **250** or the outlet **260**. The UV portion of the radiation **280** striking the wall **211** will be absorbed and disbursed as indicated above.

[0077] As discussed above, the fins **212** covering the inlet **250** and the outlet **260** also limit any line of sight of the user into the housing **210**. The fins **212** are vertically oriented within the inlet **250** and the outlet **260**. The depth D of each fin **212** is preferably deep enough to prevent an individual from directly viewing the interior wall **211**. In a preferred embodiment, an individual cannot directly view the inner surface **211** by moving from side-to-side, while looking into the outlet

260 or the inlet 250. Looking between the fins 212 and into the housing 210 allows an individual to "see through" the device 200. That is, a user can look into the inlet vent 250 or the outlet vent 260 and see out of the other vent. It is to be understood that it is acceptable to see light or a glow coming from within housing 210, if the light has a non-UV wavelength that is acceptable for viewing. In general, an user viewing into the inlet 250 or the outlet 260 may be able to notice a light or glow emitted from within the housing 210. This light is acceptable to view. In general, when the radiation 280 strikes the interior surface 211 of the housing 210, the radiation 280 is shifted from its UV spectrum. The wavelength of the radiation changes from the UV spectrum into an appropriate viewable spectrum. Thus, any light emitted from within the housing 210 is appropriate to view.

[0078] As also discussed above, the housing 210 is designed to optimize the reduction of microorganisms within the airflow. The efficacy of radiation 280 upon microorganisms depends upon the length of time such organisms are subjected to the radiation 280. Thus, the lamp 290 is preferably located within the housing 210 where the airflow is the slowest. In preferred embodiments, the lamp 290 is disposed within the housing 210 along line A-A (see Figs. 5A-7). Line A-A designates the largest width and cross-sectional area of the housing 210, perpendicular to the airflow. The housing 210 creates a fixed volume for the air to pass through. In operation, air enters the inlet 250, which has a smaller width, and cross-sectional area, than along line A-A. Since the width and cross-sectional area of the housing 210 along line A-A are larger than the width and cross-sectional area of the inlet 250, the airflow will decelerate from the inlet 250 to the line A-A. By placing the lamp 290 substantially along line A-A, the air will have the longest dwell time as it passes through the radiation 280 emitted by the lamp 290. In other words, the microorganisms within the air will be subjected to the radiation 280 for the longest period possible by placing the lamp 290 along line A-A. It is, however, within the scope of the present invention to locate the lamp 290 anywhere within the housing 210, preferably upstream of the electrode assembly 220.

[0079] A shell or housing 270 substantially surrounds the lamp 290. The shell 270

prevents the light **280** from shining directly towards the inlet **250** or the outlet **260**. In a preferred embodiment, the interior surface of the shell **270** that faces the lamp **290** is a non-reflective surface. By way of example only, the interior surface of the shell **270** may be a rough surface, or painted a dark, non-gloss color such as black. The lamp **290**, as shown in Figs. 5A-5B, is a circular tube parallel to the housing **210**. In a preferred embodiment, the lamp **290** is substantially the same length as, or shorter than, the fins **212** covering the inlet **250** and outlet **260**. The lamp **290** emits the light **280** outward in a 360^0 pattern. The shell **270** blocks the portion of the light **280** emitted directly towards the inlet **250** and the outlet **260**. As shown in Figs. 5A and 5B, there is no direct line of sight through the inlet **250** or the outlet **260** that would allow a person to view the lamp **290**. Alternatively, the shell **270** can have an internal reflective surface in order to reflect radiation into the air stream.

[0080] In the embodiment shown in Fig. 5A, the lamp **290** is located along the side of the housing **210** and near the inlet **250**. After the air passes through the inlet **250**, the air is immediately exposed to the light **280** emitted by the lamp **290**. An elongated "U"-shaped shell **270** substantially encloses the lamp **290**. The shell **270** has two mounts to support and electrically connect the lamp **290** to the power supply.

[0081] In a preferred embodiment, as shown in Fig. 5B, the shell **270** comprises two separate surfaces. The wall **274a** is located between the lamp **290** and the inlet **250**. The first wall **274a** is preferably "U"-shaped, with the concave surface facing the lamp **290**. The convex surface of the wall **274a** is preferably a non-reflective surface. Alternatively, the convex surface of the wall **274a** may reflect the light **280** outward toward the passing airflow. The wall **274a** is integrally formed with the removable rear panel **224**. When the rear panel **224** is removed from the housing **210**, the wall **274a** is also removed, exposing the germicidal lamp **290**. The germicidal lamp **290** is easily accessible in order to, as an example, replace the lamp **290** when it expires.

[0082] The wall **274b**, as shown in Fig. 5B, is "V"-shaped. The wall **274b** is located between the lamp **290** and the electrode assembly **220** to prevent a user from directly looking through the outlet **260** and viewing the UV radiation emitted from the lamp **290**. In a preferred

embodiment, the wall **274b** is also a non-reflective surface. Alternatively, the wall **274b** may be a reflective surface to reflect the light **280**. It is within the scope of the present invention for the wall **274b** to have other shapes such as, but not limited to, "U"-shaped or "C"-shaped.

[0083] The shell **270** may also have fins **272**. The fins **272** are spaced apart and preferably substantially perpendicular to the passing airflow. In general, the fins **272** further prevent the light **280** from shining directly towards the inlet **250** and the outlet **260**. The fins have a black or non-reflective surface. Alternatively, the fins **272** may have a reflective surface. Fins **272** with a reflective surface may shine more light **280** onto the passing airflow because the light **280** will be repeatedly reflected and not absorbed by a black surface. The shell **270** directs the radiation towards the fins **272**, maximizing the light emitted from the lamp **290** for irradiating the passing airflow. The shell **270** and fins **272** direct the radiation **280** emitted from the lamp **290** in a substantially perpendicular orientation to the crossing airflow traveling through the housing **210**. This prevents the radiation **280** from being emitted directly towards the inlet **250** or the outlet **260**.

Fig. 6

[0084] Fig. 6 illustrates yet another embodiment of the device **200**. The embodiment shown in Fig. 6 is a smaller, more portable, desk version of the air transporter-conditioner. Air is brought into the housing **210** through the inlet **250**, as shown by the arrows marked "IN." The inlet **250** in this embodiment is an air chamber having multiple vertical slots **251** located along each side. In this embodiment, the slots are divided across the direction of the airflow into the housing **210**. The slots **251** preferably are spaced apart a similar distance as the fins **212** in the previously described embodiments, and are substantially the same height as the side walls of the air chamber. In operation, air enters the housing **210** by entering the chamber **250** and then exiting the chamber **250** through the slots **251**. The air contacts the interior wall **211** of the housing **210** and continues to travel through the housing **210** towards the outlet **260**. Since the rear wall **253** of the chamber is a solid wall, the device **200** only requires a single non-reflective housing **270** located between the germicidal lamp **290** and the electrode assembly **220** and the outlet **260**. The housing **270** in

Fig. 6 is preferably "U"-shaped, with the convex surface **270a** facing the germicidal lamp **290**. The surface **270a** directs the light **280** toward the interior surface **211** of the housing **210** and maximizes the disbursement of radiation into the passing airflow. It is within the scope of the invention for the surface **270** to comprise other shapes such as, but not limited to, a "V"-shaped surface, or to have the concave surface **270b** face the lamp **290**. Also in other embodiments the housing **270** can have a reflective surface in order to reflect radiation into the air stream. Similar to the previous embodiments, the air passes the lamp **290** and is irradiated by the light **280** soon after the air enters the housing **210**, and prior to reaching the electrode assembly **220**.

[0085] Figs. 5A-6 illustrate embodiments of the electrode assembly **220**. The electrode assembly **220** comprises a first emitter electrode array **230** and a second particle collector electrode array **240**, which is preferably located downstream of the germicidal lamp **290**. The specific configurations of the electrode array **220** are discussed below, and it is to be understood that any of the electrode assembly configurations depicted in Figs. 8A-15C may be used in the device depicted in Figs. 2A-6. It is the electrode assembly **220** that creates ions and causes the air to flow electro-kinetically between the first emitter electrode array **230** and the second collector electrode array **240**. In the embodiments shown in Fig. 5A-6, the first array **230** comprises two wire-shaped electrodes **232**, while the second array **240** comprises three "U"-shaped electrodes **242**. Each "U"-shaped electrode has a nose **246** and two trailing sides **244**. It is within the scope of the invention for the first array **230** and the second array **240** to include electrodes having other shapes as mentioned above and described below.

<u>Electrical Circuit for the Electro-Kinetic Device:</u>

[0086] Figs. 7A-7B illustrate a preferred embodiment of an electrical block diagram for the electro-kinetic device **200** with enhanced anti-microorganism capability. Fig. 7A illustrates a preferred electrical block diagram of the germicidal lamp circuit **101**. The main components of the circuit **101** are an electromagnetic interference (EMI) filter **110**, an electronic ballast **112**, and a DC power supply **114**. The device **200** has an electrical power cord that plugs into a common

electrical wall socket. The (EMI) filter **110** is placed across the incoming 110VAC line to reduce and/or eliminate high frequencies generated by the electronic ballast **112** and the high voltage generator **170**. The electronic ballast **112** is electrically connected to the germicidal lamp **290** to regulate, or control, the flow of current through the lamp **290**. Electrical components such as the EMI Filter **110** and electronic ballast **112** are well known in the art and do not require a further description. The DC Power Supply **114** receives the 110VAC and outputs 12VDC for the internal logic of the device **200**, and 160VDC for the primary side of the transformer **116** (see Fig. 7B).

[0087] As seen in Fig. 7B, a high voltage pulse generator **170** is coupled between the first electrode array **230** and the second electrode array **240**. The generator **170** receives low input voltage, e.g., 160VDC from DC power supply **114**, and generates high voltage pulses of at least 5 KV peak-to-peak with a repetition rate of about 20 KHz. Preferably, the voltage doubler **118** outputs 9KV to the first array **230**, and 18KV to the second array **240**. It is within the scope of the present invention for the voltage doubler **118** to produce a greater or smaller voltage. The pulse train output preferably has a duty cycle of perhaps 10%, but may have other duty cycles, including a 100% duty cycle. The high voltage pulse generator **170** may be implemented in many ways, and typically will comprise a low voltage converter oscillator **124**, operating at perhaps 20 KHz frequency, that outputs low voltage pulses to an electronic switch. Such a switch is shown as an insulated gate bipolar transistor (IGBT) **126**. The IGBT **126**, or other appropriate switch, couples the low voltage pulses from the oscillator **124** to the input winding of a step-up transformer **116**. The secondary winding of the transformer **116** is coupled to the voltage doubler **118**, which outputs the high voltage pulses to the first and second array of electrodes **230**, **240**. In general, the IGBT **126** operates as an electronic on/off switch. Such a transistor is well known in the art and does not require a further description.

[0088] The converter oscillator **124** receives electrical signals from the airflow modulating circuit **120**, the power setting circuit **122**, and the boost timer **128**. The airflow rate of the device **200** is primarily controlled by the airflow modulating circuit **120** and the power setting circuit **122**.

The airflow modulating circuit **120** is a "micro-timing" gating circuit. The airflow modulating circuit **120** outputs an electrical signal that modulates between a "low" airflow signal and a "high" airflow signal. The airflow modulating circuit **120** continuously modulates between these two signals, preferably outputting the "high" airflow signal for 2.5 seconds, and then the "low" airflow signal for 5 seconds. By way of example only, the "high" airflow signal causes the voltage doubler **118** to provide 9KV to the first array **230**, while 18KV is provided to the second array **240**, and the "low" airflow signal causes the voltage doubler **118** to provide 6KV to the first array **230**, while 12KV is provided to the second array **240**. As will be described later, the voltage difference between the first and second array is proportional to the airflow rate of the device **200**. In general, a greater voltage differential is created between the first and second array by the "high" airflow signal. It is within the scope of the present invention for the airflow modulating circuit **120** to produce different voltage differentials between the first and second arrays. The various circuits and components comprising the high voltage pulse generator **170** can be fabricated on a printed circuit board mounted within housing **210**.

[0089] The power setting circuit **122** is a "macro-timing" circuit that can be set, by a control dial **214** (described hereinafter), to a LOW, MED, or HIGH setting. The three settings determine how long the signal generated by the airflow modulating circuit **120** will drive the oscillator **124**. When the control dial **214** is set to HIGH, the electrical signal output from the airflow modulating circuit **120**, modulating between the high and low airflow signals, will continuously drive the connector oscillator **124**. When the control dial **214** is set to MED, the electrical signal output from the airflow modulating circuit **120** will cyclically drive the oscillator **124** for 25 seconds, and then drop to a zero or a lower voltage for 25 seconds. Thus, the airflow rate through the device **200** is slower when the dial **214** is set to MED than when the control dial **214** is set to HIGH. When the control dial **214** is set to LOW, the signal from the airflow modulating circuit **120** will cyclically drive the oscillator **124** for 25 seconds, and then drop to a zero or a lower voltage for 75 seconds. It is within the scope and spirit of the present invention for the HIGH, MED, and LOW settings to drive the oscillator **124** for longer or shorter periods of time.

[0090] The boost timer **128** sends an electrical signal to the airflow modulating circuit **120** and the powersetting circuit **122** when the boost button **216** is depressed. The boost timer **128** when activated, instructs the airflow modulating circuit **120** to continuously drive the converter oscillator **124** as if the device **200** was set to the HIGH setting. The boost timer **128** also sends a signal to the power setting circuit **122** that shuts the powersetting circuit **122** temporarily off. In effect, the boost timer **128** overrides the setting that the device **200** is set to by the dial **214**. Therefore, the device **200** will run at a maximum airflow rate for a 5 minute period.

[0091] Fig. 7B further illustrates some preferred timing and maintenance features of the device **200**. The device **200** has a 2 week timer **130** that provides a reminder to the user to clean the device **200**, and an arc sensing circuit **132** that may shut the device **200** completely off in case of arcing.

Electrode Assembly with First and Second Electrodes:
Figs. 8A-8F

[0092] Figs. 8A-8F illustrate various configurations of the electrode assembly **220**. The output from high voltage pulse generator unit **170** is coupled to an electrode assembly **220** that comprises a first electrode array **230** and a second electrode array **240**. Again, instead of arrays, a single electrode or single conductive surface can be substituted for one or both array **230** and array **240**.

[0093] The positive output terminal of unit **170** is coupled to first electrode array **230**, and the negative output terminal is coupled to second electrode array **240**. It is believed that with this arrangement the net polarity of the emitted ions is positive, e.g., more positive ions than negative ions are emitted. This coupling polarity has been found to work well, including minimizing unwanted audible electrode vibration or hum. However, while generation of positive ions is conducive to a relatively silent airflow, from a health standpoint, it is desired that the output airflow be richer in negative ions, not positive ions. It is noted that in some embodiments, one port (preferably the

negative port) of the high voltage pulse generator **170** need not be connected to the second array of electrodes **240**. Nonetheless, there will be an "effective connection" between the second array electrodes **242** and one output port of the high voltage pulse generator **170**, in this instance, via ambient air. Alternatively the negative output terminal of unit **170** can be connected to the first electrode array **230** and the positive output terminal can be connected to the second electrode array **240**.

[0094] With this arrangement an electrostatic flow of air is created, going from the first electrode array **230** towards the second electrode array **240**. (This flow is denoted "OUT" in the figures.) Accordingly electrode assembly **220** is mounted within transporter system **100** such that second electrode array **240** is closer to the OUT vents and first electrode array **230** is closer to the IN vents.

[0095] When voltage or pulses from high voltage pulse generator **170** are coupled across first and second electrode arrays **230** and **240**, a plasma-like field is created surrounding electrodes **232** in first array **230**. This electric field ionizes the ambient air between the first and second electrode arrays and establishes an "OUT" airflow that moves towards the second array **240**. It is understood that the "IN" flow enters via vent(s) **104** or **250**, and that the "OUT" flow exits via vent(s) **106** or **260**.

[0096] Ozone and ions are generated simultaneously by the first array electrodes **232**, essentially as a function of the potential from generator **170** coupled to the first array of electrodes or conductive surfaces. Ozone generation can be increased or decreased by increasing or decreasing the potential at the first array **230**. Coupling an opposite polarity potential to the second array electrodes **242** essentially accelerates the motion of ions generated at the first array **230**, producing the airflow denoted as "OUT" in the figures. As the ions and ionized particles move toward the second array **240**, the ions and ionized particles push or move air molecules toward the second array **240**. The relative velocity of this motion may be increased, by way of example, by decreasing the potential at the second array **240** relative to the potential at the first array **230**.

[0097] For example, if +10 KV were applied to the first array electrode(s) **232**, and no potential were applied to the second array electrode(s) **242**, a cloud of ions (whose net charge is positive) would form adjacent the first electrode array **230**. Further, the relatively high 10 KV potential would generate substantial ozone. By coupling a relatively negative potential to the second array electrode(s) **242**, the velocity of the air mass moved by the net emitted ions increases.

[0098] On the other hand, if it were desired to maintain the same effective outflow (OUT) velocity, but to generate less ozone, the exemplary 10 KV potential could be divided between the electrode arrays. For example, generator **170** could provide +4 KV (or some other fraction) to the first array electrodes **232** and -6 KV (or some other fraction) to the second array electrodes **242**. In this example, it is understood that the +4 KV and the -6 KV are measured relative to ground. Understandably it is desired that the unit **100** operates to output appropriate amounts of ozone. Accordingly, the high voltage is preferably fractionalized with about +4 KV applied to the first array electrodes **232** and about -6 KV applied to the second array electrodes **242**.

[0099] In the embodiments of Figs. 8A and 8B, electrode assembly **220** comprises a first array **230** of wire-shaped electrodes **232**, and a second array **240** of generally "U"-shaped electrodes **242**. In preferred embodiments, the number N1 of electrodes comprising the first array **230** can preferably differ by one relative to the number N2 of electrodes comprising the second array **240**. In many of the embodiments shown, N2>N1. However, if desired, additional first electrodes **232** could be added at the outer ends of array **230** such that N1>N2, e.g., five first electrodes **232** compared to four second electrodes **242**.

[0100] As previously indicated, first or emitter electrodes **232** are preferably lengths of tungsten wire, whereas electrodes **242** are formed from sheet metal, preferably stainless steel, although brass or other sheet metal could be used. The sheet metal is readily configured to define side regions **244** and a bulbous nose region **246**, forming the hollow, elongated "U"-shaped electrodes **242**. While Fig. 8A depicts four electrodes **242** in second array **240** and three electrodes **232** in first array **230**, as noted previously, other numbers of electrodes in each array could be used, preferably retaining a symmetrically staggered configuration as shown. It is seen in

Fig. 8A that while particulate matter **60** is present in the incoming (IN) air, the outflow (OUT) air is substantially devoid of particulate matter, which adheres to the preferably large surface area provided by the side regions **244** of the second array electrodes **242**.

[0101] Fig. 8B illustrates that the spaced-apart configuration between the first and second arrays **230, 240** is staggered. Preferably, each first array electrode **232** is substantially equidistant from two second array electrodes **242**. This symmetrical staggering has been found to be an efficient electrode placement. Preferably, in this embodiment, the staggering geometry is symmetrical in that adjacent electrodes **232** or adjacent electrodes **242** are spaced-apart a constant distance, Y1 and Y2 respectively. However, a non-symmetrical configuration could also be used. Also, it is understood that the number of electrodes **232** and **242** may differ from what is shown.

[0102] In the embodiment of Figs. 8A, typically dimensions are as follows: diameter of electrodes **232**, R1, is about 0.08 mm, distances Y1 and Y2 are each about 16 mm, distance X1 is about 16 mm, distance L is about 20 mm, and electrode heights Z1 and Z2 are each about 1 m. The width W of electrodes **242** is preferably about 4 mm, and the thickness of the material from which electrodes **242** are formed is about 0.5 mm. Of course, other dimensions and shapes could be used. For example, preferred dimensions for distance X1 may vary between 12-30mm, and the distance Y2 may vary between 15-30mm. It is preferred that electrodes **232** have a small diameter, such as R1 shown in Fig. 8B. The small diameter electrode generates a high voltage field and has a high emissivity. Both characteristics are beneficial for generating ions. At the same time, it is desired that electrodes **232** (as well as electrodes **242**) be sufficiently robust to withstand occasional cleaning.

[0103] Electrodes **232** in first array **230** are electrically connected to a first (preferably positive) output port of high voltage pulse generator **170** by a conductor **234**. Electrodes **242** in second array **240** are electrically connected to a second (preferably negative) output port of high voltage generator **170** by a conductor **249**. The first and second electrodes may be electrically connected to the high voltage generator **170** at various locations. By way of example only, Fig. 8B

depicts conductor **249** making connection with some electrodes **242** internal to nose **246**, while other electrodes **242** make electrical connection to conductor **249** elsewhere on the electrode **242**. Electrical connection to the various electrodes **242** could also be made on the electrode external surface, provided no substantial impairment of the outflow airstream results; however it has been found to be preferable that the connection is made internally.

[0104] In this and the other embodiments to be described herein, ionization appears to occur at the electrodes **232** in the first electrode array **230**, with ozone production occurring as a function of high voltage arcing. For example, increasing the peak-to-peak voltage amplitude and/or duty cycle of the pulses from the high voltage pulse generator **170** can increase ozone content in the output flow of ionized air. If desired, user-control **S2** or the dial **214** can be used to somewhat vary ozone content by varying amplitude and/or duty cycle. Specific circuitry for achieving such control is known in the art and need not be described in detail herein.

[0105] Note the inclusion in Figs. 8A and 8B of at least one output controlling electrodes **243**, preferably electrically coupled to the same potential as the second array electrodes **242**. Electrode **243** preferably defines a pointed shape in side profile, e.g., a triangle. The sharp point on electrodes **243** causes generation of substantial negative ions (since the electrode is coupled to relatively negative high potential). These negative ions neutralize excess positive ions otherwise present in the output airflow, such that the "OUT" flow has a net negative charge. Electrode **243** is preferably manufactured from stainless steel, copper, or other conductor material, and is perhaps 20 mm high and about 12 mm wide at the base. The inclusion of one electrode **243** has been found sufficient to provide a sufficient number of output negative ions, but more such electrodes may be included.

[0106] In the embodiments of Figs. 8A, 8B and 8C, each "U"-shaped electrode **242** has two trailing surface or sides **244** that promote efficient kinetic transport of the outflow of ionized air and ozone. For the embodiment of Fig. 8C, there is the inclusion on at least one portion of a trailing edge of a pointed electrode region **243'**. Electrode region **243'** helps promote output of negative ions, in the same fashion that was previously described with respect to electrodes **243**,

as shown in Figs. 8A and 8B.

[0107] In Fig. 8C and the figures to follow, the particulate matter is omitted for ease of illustration. However, from what was shown in Figs. 8A-8B, particulate matter will be present in the incoming air, and will be substantially absent from the outgoing air. As has been described, particulate matter **60** typically will be electrostatically precipitated upon the surface area of electrodes **242**.

[0108] As discussed above and as depicted by Fig. 8C, it is relatively unimportant where on an electrode array the electrical connection is made with the high voltage generator **170**. In this embodiment, first array electrodes **232** are shown electrically connected together at their bottom regions by conductor **234**, whereas second array electrodes **242** are shown electrically connected together in their middle regions by the conductor **249**. Both arrays may be connected together in more than one region, e.g., at the top and at the bottom. It is preferred that the wire or strips or other inter-connecting mechanisms be at the top, bottom, or periphery of the second array electrodes **242**, so as to minimize obstructing stream air movement through the housing **210**.

[0109] It is noted that the embodiments of Figs. 8C and 8D depict somewhat truncated versions of the second electrodes **242**. Whereas dimension L in the embodiment of Figs. 8A and 8B was about 20 mm, in Figs. 8C and 8D, L has been shortened to about 8 mm. Other dimensions in Fig. 8C preferably are similar to those stated for Figs. 8A and 8B. It will be appreciated that the configuration of second electrode array **240** in Fig. 8C can be more robust than the configuration of Figs. 8A and 8B, by virtue of the shorter trailing edge geometry. As noted earlier, a symmetrical staggered geometry for the first and second electrode arrays is preferred for the configuration of Fig. 8C.

[0110] In the embodiment of Fig. 8D, the outermost second electrodes, denoted **242-1** and **242-4**, have substantially no outermost trailing edges. Dimension L in Fig. 8D is preferably about 3 mm, and other dimensions may be as stated for the configuration of Figs. 8A and 8B. Again, the ratio of the radius or surface areas between the first electrode **232** and the second electrodes **242** for the embodiment of Fig. 8D preferably exceeds about 20:1.

[0111] Figs. 8E and 8F depict another embodiment of electrode assembly **220**, in which the first electrode array **230** comprises a single wire electrode **232**, and the second electrode array **240** comprises a single pair of curved "L"-shaped electrodes **242**, in cross-section. Typical dimensions, where different than what has been stated for earlier-described embodiments, are X1 ≈ 12 mm, Y2 ≈ 5 mm, and L1 ≈ 3 mm. The effective surface area or radius ratio between the electrode arrays is again greater than about 20:1. The fewer electrodes comprising assembly **220** in Figs. 8E and 8F promote economy of construction, and ease of cleaning, although more than one electrode **232**, and more than two electrodes **242** could of course be employed. This particular embodiment incorporates the staggered symmetry described earlier, in which electrode **232** is equidistant from two electrodes **242**. Other geometric arrangements, which may not be equidistant, are within the spirit and scope of the invention.

Electrode Assembly With an Upstream Focus Electrode:

Figs. 9A-9B

[0112] The embodiments illustrated in Figs. 9A-9B are somewhat similar to the previously described embodiments in Figs. 8A-8B. The electrode assembly **220** includes a first array of electrodes **230** and a second array of electrodes **240**. Again, for this and the other embodiments, the term "array of electrodes" may refer to a single electrode or a plurality of electrodes. Preferably, the number of electrodes **232** in the first array of electrodes **230** will differ by one relative to the number of electrodes **242** in the second array of electrodes **240**. The distances L, X1, Y1, Y2, Z1 and Z2 for this embodiment are similar to those previously described in Fig. 8A.

[0113] As shown in Fig. 9A, the electrode assembly **220** preferably adds a third, or leading, or focus, or directional electrode **224a, 224b, 224c** (generally referred to as "electrode **224**") upstream of each first electrode **232-1, 232-2, 232-3**. The focus electrode **224** creates an enhanced airflow velocity exiting the devices **100** or **200**. In general, the third focus electrode **224** directs the airflow, and ions generated by the first electrode **232**, towards the second electrodes **242**. Each third focus electrode **224** is a distance X2 upstream from at least one of the first

electrodes **232**. The distance X2 is preferably 5-6 mm, or four to five diameters of the focus electrode **224**. However, the third focus electrode **224** can be further from, or closer to, the first electrode **232**.

[0114] The third focus electrode **224** illustrated in Fig. 9A is a rod-shaped electrode. The third focus electrode **224** can also comprise other shapes that preferably do not contain any sharp edges. The third focus electrode **224** is preferably manufactured from material that will not erode or oxidize, such as stainless steel. The diameter of the third focus electrode **224**, in a preferred embodiment, is at least fifteen times greater than the diameter of the first electrode **232**. The diameter of the third focus electrode **224** can be larger or smaller. The diameter of the third focus electrode **224** is preferably large enough so that third focus electrode **224** does not function as an ion emitting surface when electrically connected with the first electrode **232**. The maximum diameter of the third focus electrode **224** is somewhat constrained. As the diameter increases, the third focus electrode **224** will begin to noticeably impair the airflow rate of the units **100** or **200**. Therefore, the diameter of the third electrode **224** is balanced between the need to form a non-ion emitting surface and airflow properties of the unit **100** or **200**.

[0115] In a preferred embodiment, each third focus electrode **224a**, **224b**, **224c** are electrically connected with the first array **230** and the high voltage generator **170** by the conductor **234**. As shown in Fig. 9A, the third focus electrodes **224** are electrically connected to the same positive outlet of the high voltage generator **170** as the first array **230**. Accordingly, the first electrode **232** and the third focus electrode **224** generate a positive electrical field. Since the electrical fields generated by the third focus electrode **224** and the first electrode **232** are both positive, the positive field generated by the third focus electrode **224** can push, or repel, or direct, the positive field generated by the first electrode **232** towards the second array **240**. For example, the positive field generated by the third focus electrode **224a** will push, or repel, or direct, the positive field generated by the first electrode **232-1** towards the second array **240**. In general, the third focus electrode **224** shapes the electrical field generated by each electrode **232** in the first array **230**. This shaping effect is believed to decrease the amount of ozone

generated by the electrode assembly **220** and increases the airflow of the units **100** and **200**.

[0116] The particles within the airflow are positively charged by the ions generated by the first electrode **232**. As previously mentioned, the positively charged particles are collected by the negatively charged second electrodes **242**. The third focus electrode **224** also directs the airflow towards the trailing sides **244** of each second electrode **242**. For example, it is believed that the airflow will travel around the third focus electrode **224**, partially guiding the airflow towards the trailing sides **244**, improving the collection rate of the electrode assembly **220**.

[0117] The third focus electrode **224** may be located at various positions upstream of each first electrode **232**. By way of example only, a third focus electrode **224b** is located directly upstream of the first electrode **232-2** so that the center of the third focus electrode **224b** is in-line and symmetrically aligned with the first electrode **232-2**, as shown by extension line B. Extension line B is located midway between the second electrode **242-2** and the second electrode **242-3**. Alternatively, a third focus electrode **224** may also be located at an angle relative to the first electrode **232**. For example, a third focus electrode **224a** may be located upstream of the first electrode **232-1** along a line extending from the middle of the nose **246** of the second electrode **242-2** through the center of the first electrode **232-1**, as shown by extension line A. The third focus electrode **224a** is in-line and symmetrically aligned with the first electrode **232-1** along extension line A. Similarly, the third electrode **224c** is located upstream to the first electrode **232-3** along a line extending from the middle of the nose **246** of the second electrode **242-3** through the first electrode **232-3**, as shown by extension line C. The third focus electrode **224c** is in-line and symmetrically aligned with the first electrode **232-3** along extension line C. It is within the scope of the present invention for the electrode assembly **220** to include third focus electrodes **224** that are both directly upstream and at an angle to the first electrodes **232**, as depicted in Fig. 9A. Thus, the focus electrodes **224** fan out relative to the first electrodes **232**.

[0118] Fig. 9B illustrates that an electrode assembly **220** may contain multiple third focus electrodes **224** upstream of each first electrode **232**. By way of example only, the third focus electrode **224a2** is in-line and symmetrically aligned with the third focus electrode **224a1**, as

shown by extension line A. In a preferred embodiment, only the third focus electrodes **224a1**, **224b1**, **224c1** are electrically connected to the high voltage generator **170** by conductor **234**. Accordingly, not all of the third electrodes **224** are at the same operating potential. In the embodiment shown in Fig. 9B, the third focus electrodes **224a1**, **224b1**, **224c1** are at the same electrical potential as the first electrodes **232**, while the third focus electrodes **224a2**, **224b2**, **224c2** are floating. Alternatively, the third focus electrodes **224a2**, **224b2** and **224c2** may be electrically connected to the high voltage generator **170** by the conductor **234**.

[0119] Fig. 9B illustrates that each second electrode **242** may also have a protective end **241**. In the previous embodiments, each "U"-shaped second electrode **242** has an open end. Typically, the end of each trailing side or side wall **244** contains sharp edges. The gap between the trailing sides or side walls **244**, and the sharp edges at the end of the trailing sides or side walls **244**, generate unwanted eddy currents. The eddy currents create a "backdraft," or airflow traveling from the outlet towards the inlet, which slows down the airflow rate of the units **100** or **200**.

[0120] In a preferred embodiment, the protective end **241** is created by shaping, or rolling, the trailing sides or side walls **244** inward and pressing them together, forming a rounded trailing end with no gap between the trailing sides or side walls of each second electrode **242**. Accordingly, the side walls **244** have outer surfaces, and the end of the side walls **244** are bent back inward and towards the nose **246** so that the outer surface of the side walls **244** are adjacent to, or face, or touch each other to form a smooth trailing edge on the second electrode **242**. If desired, it is within the scope of the invention to spot weld the rounded ends together along the length of the second electrode **242**. It is also within the scope of the present invention to form the protective end **241** by other methods such as, but not limited to, placing a strap of plastic across each end of the trailing sides **244** for the full length of the second electrode **242**. The rounded or capped end is an improvement over the previous electrodes **242** without a protective end **241**. Eliminating the gap between the trailing sides **244** also reduces or eliminates the eddy currents typically generated by the second electrode **242**. The rounded protective end

also provides a smooth surface for purpose of cleaning the second electrode. In a preferred embodiment, the second or collector electrode **242** is a one-piece, integrally formed, electrode with a protective end.

Figs. 10A-10D

[0121] Fig. 10A illustrates an electrode assembly **220** including a first array of electrodes **230** having three wire-shaped first electrodes **232-1**, **232-2**, **232-3** (generally referred to as "electrode **232**") and a second array of electrodes **240** having four "U"-shaped second electrodes **242-1**, **242-2**, **242-3**, **242-4** (generally referred to as "electrode **242**"). Each first electrode **232** is electrically connected to the high voltage generator **170** at the bottom region, whereas each second electrode **242** is electrically connected to the high-voltage generator **170** in the middle to illustrate that the first and second electrodes **232**, **242** can be electrically connected in a variety of locations.

[0122] The second electrode **242** in Fig. 10A is a similar version of the second electrode **242** shown in Fig. 8C. The distance L has been shortened to about 8mm, while the other dimensions X1, Y1, Y2, Z1, Z2 are similar to those shown in Fig. 8A.

[0123] A third leading or focus electrode **224** is located upstream of each first electrode **232**. The innermost third focus electrode **224b** is located directly upstream of the first electrode **232-2**, as shown by extension line B. Extension line B is located midway between the second electrodes **242-2**, **242-3**. The third focus electrodes **224a**, **224c** are at an angle with respect to the first electrodes **232-1**, **232-3**. For example, the third focus electrode **224a** is upstream to the first electrode **232-1** along a line extending from the middle of the nose **246** of the second electrode **242-2** extending through the center of the first electrode **232-1**, as shown by extension line A. The third electrode **224c** is located upstream of the first electrode **232-3** along a line extending from the center of the nose **246** of the second electrode **242-3** through the center of the first electrode **232-3**, as shown by extension line C. Preferably, the focus electrodes **224** fan out relative to the first electrodes **232** as an aid for directing the flow of ions and charged

particles. Fig. 10B illustrates that the third focus electrodes **224** and the first electrode **232** may be electrically connected to the high voltage generator **170** by conductor **234**.

[0124] Fig. 10C illustrates that a pair of third focus electrodes **224** may be located upstream of each first electrode **232**. Preferably, the multiple third focus electrodes **224** are in-line and symmetrically aligned with each other. For example, the third focus electrode **224a2** is in-line and symmetrically aligned with the third focus electrode **224a1**, along extension line A. As previously mentioned, preferably only third focus electrodes **224a1**, **224b1**, **224c1** are electrically connected with the first electrodes **232** by conductor **234**. It is also within the scope of the present invention to have none or all of the third focus electrodes **224** electrically connected to the high voltage generator **170**.

[0125] Fig. 10D illustrates third focus electrodes **224** added to the electrode assembly **220** shown in Fig. 8D. Preferably, a third focus electrode **224** is located upstream of each first electrode **232**. For example, the third focus electrode **224b** is in-line and symmetrically aligned with the first electrode **232-2**, as shown by extension line B. Extension line B is located midway between the second electrodes **242-2**, **242-3**. The third focus electrode **224a** is in-line and symmetrically aligned with the first electrode **232-1**, as shown by extension line A. Similarly, the third electrode **224c** is in-line and symmetrically aligned with the first electrode **232-3**, as shown by extension line C. Extension lines A and C extend from the middle of the nose **246** of the "U"-shaped second electrodes **242-2**, **242-3** through the first electrodes **232-1**, **232-3**, respectively. In a preferred embodiment, the third electrodes **224a**, **224b**, **224c** with the high voltage generator **170** by the conductor **234**. This embodiment can also include a pair of third focus electrodes **224** upstream of each first electrode **232** similar to the embodiment depicted in Fig. 10C.

<u>Figs. 11A-11C</u>

[0126] Figs. 11A-11C illustrate that the electrode assembly **220** shown in Fig. 8E may include a third focus electrode **224** upstream of the first array of electrodes **230** comprising a

single wire electrode **232**. Preferably, the center of the third focus electrode **224** is in-line and symmetrically aligned with the center of the first electrode **232**, as shown by extension line B. Extension line B is located midway between the second electrodes **242**. The distances X1, X2, Y1, Y2, Z1 and Z2 are similar to the embodiments previously described. The first electrode **232** and the second electrodes **242** may be electrically connected to the high-voltage generator **170** by conductor **234, 249** respectively. It is within the scope of the present invention to connect the first and second electrodes to opposite ends of the high voltage generator **170** (e.g., the first electrode **232** may be negatively charged and the second electrode **242** may be positively charged). In a preferred embodiment, the third focus electrode **224** is also electrically connected to the high voltage generator **170**.

[0127] Fig. 11B illustrates that a pair of third focus electrodes **224a, 224b** may be located upstream of the first electrode **232**. The third focus electrodes **224a, 224b** are in-line and symmetrically aligned with the first electrode **232**, as shown by extension line B. Extension line B is located midway between the second electrodes **242**. Preferably, the third focus electrode **224b** is upstream of third focus electrode **224a** a distance equal to the diameter of a third focus electrode **224**. In a preferred embodiment, only the third focus electrode **224a** is electrically connected to the high voltage generator **170**. It is within the scope of the present invention to electrically connect both third focus electrodes **224a, 224b** to the high voltage generator **170**.

[0128] Fig. 11C illustrates that each third focus electrode **224** can be located at an angle with respect to the first electrode **232**. Similar to the previous embodiments, the third focus electrode **224a1** and **224b1** is located a distance X2 upstream from the first electrode **232**. By way of example only, the third focus electrodes **224a1, 224a2** are located along a line extending from the middle of the second electrode **242-2** through the center of the first electrode **232**, as shown by extension line A. Similarly, the third focus electrodes **224b1, 224b2** are along a line extending from the middle of the second electrode **242-1** through the middle of the first electrode **232**, as shown by extension line B. The third focus electrode **224a2** is in-line and symmetrically aligned with the third focus electrode **224a1** along extension line A. Similarly, the third focus

electrode **224b2** is in line and symmetrically aligned with the third focus electrode **224b1**, along extension line B. The third focus electrodes **224** are fanned out and form a "V" pattern upstream of first electrode **232**. In a preferred embodiment, only the third focus electrodes **224a1** and **224b1** are electrically connected to the high-voltage generator **170** by conductor **234**. It is within the scope and spirit of the invention to electrically connect the third focus electrodes **224a** and **224b2** to the high voltage generator **170**.

Figs. 12A-12B

[0129] The previously described embodiments of the electrode assembly **220** disclose a rod- shaped third focus electrode **224** upstream of the first array of electrodes **230**. Fig. 12A illustrates an alternative configuration for the third focus electrode **224**. By way of example only, the electrode assembly **220** may include a "U"-shaped or possibly "C"-shaped third focus electrode **224** upstream of each first electrode **232**. The third focus electrode **224** may also have other curved configurations such as, but not limited to, circular-shaped, elliptical-shaped, parabolically-shaped, and other concave shapes facing the first electrode **232**. In a preferred embodiment, the third focus electrode **224** has holes **225** extending through, forming a perforated surface to minimize the resistance of the third focus electrode **224** on the airflow rate.

[0130] In a preferred embodiment, the third focus electrode **224** is electrically connected to the high voltage generator **170** by conductor **234**. The third focus electrode **224** in Fig. 12A is preferably not an ion emitting surface. Similar to previous embodiments, the third focus electrode **224** generates a positive electric field and pushes or repels the electric field generated by the first electrode **232** towards the second array **240**.

[0131] Fig. 12B illustrates that a perforated "U"-shaped or "C"-shaped third focus electrode **224** can be incorporated into the electrode assembly **220** shown in Fig. 8A. Even though only two configurations of the electrode assembly **220** are shown with the perforated "U"-shaped third focus electrode **224**, all the embodiments described in Figs. 8A-15C may incorporate the perforated "U"-shaped third focus electrode **224**. It is also within the scope of

the invention to have multiple perforated "U"-shaped third focus electrodes **224** upstream of each first electrode **232**. Further in other embodiments the "U"-shaped third focus electrode **224** can be made of a screen or a mesh.

[0132] Fig. 12C illustrates third focus electrodes **224** similar to those depicted in Fig. 12B, except that the third focus electrodes **224** are rotated by 180° to preset a convex surface facing to the first electrodes **232** in order to focus and direct the field of ions and airflow from the first electrode **232** toward the second array of electrodes **240**. These third focus electrodes **224** shown in Figs. 12A-12C are located along extension lines A, B, C similar to previously described embodiments.

<u>Electrode Assembly With a Downstream Trailing Electrode:</u>

<u>Figs. 13A-13C</u>

[0133] Figs. 13A-13C illustrate an electrode assembly **220** having an array of trailing electrodes **245** added to an electrode assembly **220** similar to that shown in Fig. 11A. It is understood that an alternative embodiment similar to Fig. 13A may include a trailing electrode or electrodes without any focus electrodes and be within the spirit and scope of the invention.

[0134] Referring now to Figs. 13A-13B, each trailing electrode **245** is located downstream of the second array of electrodes **240**. Preferably, the trailing electrodes **245** are located downstream from each second electrode **242** by at least three times the radius R2 (see Fig. 13B). Further, the trailing electrodes **245** are preferably directly downstream of each second electrode **242** so as not to interfere with the flow of air. Also, the trailing electrode **245** is aerodynamically smooth, for example, circular, elliptical, or teardrops shaped in cross-section so as not to unduly interfere with the smoothness of the airflow thereby. In a preferred embodiment, the trailing electrodes **245** are electrically connected to the same outlet of the high voltage generator **170** as the second array of electrodes **240**. As shown in Fig. 13A, the second electrodes **242** and the trailing electrodes **245** have a negative electrical charge. This arrangement can introduce more negative charges into the air stream. Alternatively, the trailing

electrodes **245** can have a floating potential if they are not electrically connected to the second electrode **242** or the high voltage generator **170**. The trailing electrodes **245** can also be grounded in other embodiments.

[0135] When the trailing electrodes **245** are electrically connected to the high voltage generator **170**, the positively charged particles within the airflow are also attracted to, and collect on, the trailing electrodes **245**. In an electrode assembly **220** with no trailing electrode **245**, most of the particles will collect on the surface area of the second electrodes **242**. However, some particles will pass through the unit **200** without being collected by the second electrodes **242**. Thus, the trailing electrodes **245** serve as a second surface area to collect the positively charged particles. The trailing electrodes **245**, having the same polarity as the second electrodes **242**, also deflect charged particles toward the second electrodes **242**.

[0136] The trailing electrodes **245** preferably also emit a small amount of negative ions into the airflow. The negative ions emitted by the trailing electrode **245** attempt to neutralize the positive ions emitted by the first electrodes **232**. If the positive ions emitted by the first electrodes **232** are not neutralized before the airflow reaches the outlet **260**, the outlet fins **212** may become electrically charged, and particles within the airflow may tend to stick to the fins **212**. If this occurs, the particles collected by the fins **212** will eventually block or minimize the airflow exiting the unit **200**.

[0137] Fig. 13C illustrates another embodiment of the electrode assembly **200**, having trailing electrodes **245** added to an embodiment similar to that shown in Fig. 11C. The trailing electrodes **245** are located downstream of the second array **240** similar to the previously described embodiments above. It is within the scope of the present invention to electrically connect the trailing electrodes **245** to the high voltage generator **170**. The trailing electrodes **245** emit negative ions to neutralize the positive ions emitted by the first electrode **232**. As shown in Fig. 13C, all of the third focus electrodes **224** are electrically connected to the high voltage generator **170**. In a preferred embodiment, only the third focus electrodes **224a1**, **224b1** are electrically connected to the high voltage generator **170**, and the third focus electrodes **224a2**,

224b2 have a floating potential.

Electrode Assemblies With Various Combinations of Focus Electrodes, Trailing Electrodes and Enhanced Second Electrodes With Protective Ends:

Figs. 14A-14D

[0138] Fig. 14A illustrates an electrode assembly **220** that includes a first array of electrodes **230** having two wire-shaped electrodes **232-1**, **232-2** (generally referred to as "electrode **232**") and a second array of electrodes **240** having three "U"-shaped electrodes **242-1**, **242-2**, **242-3** (generally referred to as "electrode **242**"). Upstream from each first electrode **232**, at a distance X2, is a third focus electrode **224**. Each third focus electrode **224a**, **224b** is at an angle with respect to a first electrode **232**. For example, the third focus electrode **224a** is preferably along a line extending from the middle of the nose **246** of the innermost second electrode **242-2** through the center of the first electrode **232-1**, as shown by extension line A. The third focus electrode **224a** is in-line and symmetrically aligned with the first electrode **232-1** along extension line A. Similarly, the third focus electrode **224b** is located along a line extending from middle of the nose **246** of the second electrode **242-2** through the center of the first electrode **232-2**, as shown by extension line B. The third focus electrode **224b** is in-line and symmetrically aligned with the first electrode **232-2** along extension line B. As previously described, the diameter of each third focus electrode **224** is preferably at least fifteen times greater than the diameter of the first electrode **232**. As shown in Fig. 14A, and similar to the embodiment shown in Fig. 9B, each second electrode preferably has a protective end **241**. Similar to previous embodiments, the third focus electrodes **224** are preferably electrically connected to the high voltage generator **170**. It is within the spirit and scope of the invention to not electrically connect the third focus electrodes **224** with the high voltage generator **170**.

[0139] Fig. 14B illustrates that multiple third focus electrodes **224** may be located upstream of each first emitter electrode **232**. For example, the third focus electrode **224a2** is in-line and symmetrically aligned with the third focus electrode **224a1** along extension line A.

Similarly, the third focus electrode **224b2** is in-line and symmetrically aligned with the third focus electrode **242b1** along extension line B. It is within the scope of the present invention to electrically connect all, or none of, the third focus electrodes **224** to the high-voltage generator **170**. In a preferred embodiment, only the third focus electrodes **224a1**, **224b1** are electrically connected to the high voltage generator **170**, while the third focus electrodes **224a2**, **224b2** have a floating potential.

[0140] Fig. 14C illustrates that the electrode assembly **220** shown in Fig. 14A may also include a trailing electrode **245** downstream of each second electrode **242**. Each trailing electrode **245** is in-line with the second electrode **242** to minimize the interference with the airflow passing the second electrode **242**. Each trailing electrode **245** is preferably located a distance downstream of each second electrode **242** equal to at least three times the width W of the second electrode **242**. It is within the scope of the present invention to locate the trailing electrode **245** at other distances downstream of the second electrode **242**. The diameter of the trailing electrode **245** is preferably no greater than the width W of the second electrode **242** to limit the interference of the airflow coming off the second electrode **242**.

[0141] Another aspect of the trailing electrode **245** is to direct the air trailing off the second electrode **242** to provide a more laminar flow of air exiting the outlet **260**. Yet another aspect of the trailing electrode **245**, as previously mentioned above, is to neutralize the positive ions generated by the first array **230** and collect particles within the airflow. As shown in Fig. 14C, each trailing electrode **245** is electrically connected to a second electrode **242** by a conductor **248**. Similar to previous embodiments, the trailing electrode **245** has the same polarity as the second electrode **242**, and serves as a collecting surface, similar to the second electrode **242**, to attract the oppositely charged particles in the airflow. Alternatively, the trailing electrode may be connected to a ground or having a floating potential.

[0142] Fig. 14D illustrates that a pair of third focus electrodes **224** may be located upstream of each first electrode **232**. For example, the third focus electrode **224a2** is upstream of the third focus electrode **224a1** so that the third focus electrodes **224a1**, **224a2** are in-line

and symmetrically aligned with each other along extension line A. Similarly, the third focus electrode **224b2** is in line and symmetrically aligned with the third focus electrode **224b1** along extension line B. As previously described, preferably only the third focus electrodes **224a1**, **224b1** are electrically connected to the high voltage generator **170**, while the third focus electrodes **224a2**, **224b2** have a floating potential. It is within the spirit and scope of the present invention to electrically connect all, or none, of the third focus electrodes to the high voltage generator **170**.

<u>Electrode Assemblies With Second Collector Electrodes Having Interstitial Electrodes: Figs. 14E-14F</u>

[0143] Fig. 14E illustrates another embodiment of the electrode assembly **220** with an interstitial electrode **246**. In this embodiment, the interstitial electrode **246** is located midway between the second electrodes **242**. For example, the interstitial electrode **246a** is located midway between the second electrodes **242-1**, **242-2**, while the interstitial electrode **246b** is located midway between second electrodes **242-2**, **242-3**. Preferably, the interstitial electrode **246a**, **246b** are electrically connected to the first electrodes **232**, and generate an electrical field with the same positive or negative charge as the first electrodes **232**. The interstitial electrode **246** and the first electrode **232** then have the same polarity. Accordingly, particles traveling toward the interstitial electrode **246** will be repelled by the interstitial electrode **246** towards the second electrodes **242**. Alternatively, the interstitial electrodes can have a floating potential or be grounded.

[0144] It is to be understood that interstitial electrodes **246a**, **246b** may also be closer to one second collector electrode than to the other. Also, the interstitial electrodes **246a**, **246b** are preferably located substantially near or at the protective end **241** or ends of the trailing sides **244**, as depicted in Fig. 14E. Still further the interstitial electrode can be substantially located along a line between the two trailing portions or ends of the second electrodes. These rear positions are preferred as the interstitial electrodes can cause the positively charged particle to

deflect towards the trailing sides **244** along the entire length of the negatively charged second collector electrode **242**, in order for the second collector electrode **242** to collect more particles from the airflow.

[0145] Still further, the interstitial electrodes **246a, 246b** can be located upstream along the trailing side **244** of the second collector electrodes **244**. However, the closer the interstitial electrodes **246a, 246b** get to the nose **246** of the second electrode **242**, generally the less effective interstitial electrodes **246a, 246b** are in urging positively charged particles toward the entire length the second electrodes **242**. Preferably, the interstitial electrodes **246a, 246b** are wire-shaped and smaller or substantially smaller in diameter than the width "W" of the second collector electrodes **242**. For example, the interstitial electrodes can have a diameter of, the same as, or on the order, of the diameter of the first electrodes. For example, the interstitial electrodes can have a diameter of one-sixteenth of an inch. Also, the diameter of the interstitial electrodes **246a, 246b** is substantially less than the distance between second collector electrodes, as indicated by Y2. Further the interstitial electrode can have a length or diameter in the downstream direction that is substantially less than the length of the second electrode in the downstream direction. The reason for this size of the interstitial electrodes **246a, 246b** is so that the interstitial electrodes **246a, 246b** have a minimal effect on the airflow rate exiting the device **100** or **200**.

[0146] Fig. 14F illustrates that the electrode assembly **220** in Fig. 14E can include a pair of third electrodes **224** upstream of each first electrode **232**. As previously described, the pair of third electrodes **224** are preferably in-line and symmetrically aligned with each other. For example, the third electrode **224a2** is in-line and symmetrically aligned with the third electrode **224a1** along extension line A. Extension line A preferably extends from the middle of the nose **246** of the second electrode **242-2** through the center of the first electrode **232-1**. As previously disclosed, in a preferred embodiment, only the third electrodes **224a1, 224b1** are electrically connected to the high voltage generator **170**. In Fig. 14F, a plurality of interstitial electrode **296a** and **246b** are located between the second electrodes **242**. Preferably these interstitial electrodes

are in-line and have a potential gradient with an increasing voltage potential on each successive interstitial electrode in the downstream direction in order to urge particles toward the second electrodes. In this situation the voltage on the interstitial electrodes would have the same sign as the voltage on the first electrode **232**.

Electrode Assembly With an Enhanced First Emitter Electrode Being Slack: Figs. 15A-15C

[0147] The previously described embodiments of the electrode assembly **220** include a first array of electrodes **230** having at least one wire or rod shaped electrode **232**. It is within the scope of the present invention for the first array of electrodes **230** to contain electrodes consisting of other shapes and configurations.

[0148] Fig. 15A illustrates that the first array of electrodes **230** may include curved or slack wire-shaped electrodes **252**. The curved wire-shaped electrode **252** is an ion emitting surface and generates an electric field similar to the previously described wire-shaped electrodes **232**. In this embodiment, the electrode assembly **220** includes a first array of electrodes **230** having three curved electrodes **252**, and a second array of electrodes **240** having four "U"-shaped electrodes **242**. Each second electrode **242** is "downstream," and each third focus electrode **224** is "upstream," to the curved wire-shaped electrodes **252** similar to the embodiment shown in Fig. 9A. The electrical properties and characteristics of the second electrodes **242** and third focus electrode **224** are similar to the previously described embodiment shown in Fig. 9A. It is to be understood that an alternative embodiment of Fig. 15A can exclude the focus electrodes and be within the spirit and scope of the invention.

[0149] As shown in Fig. 15A, positive ions are generated and emitted by the first electrode **252**. In general, the quantity of negative ions generated and emitted by the first electrode is proportional to the surface area of the first electrode. The height Z1 of the first electrode **252** is equal to the height Z1 of the previously disclosed wire-shaped electrode **232**. However, the total length of the electrode **252** is greater than the total length of the electrode

232. By way of example only, and in a preferred embodiment, if the electrode **252** was straightened out, the curved or slack wire electrode **252** is 15-30% longer than the rod or wire-shaped electrode **232**. The curved electrode **252** is allowed to be slack to achieve the shorter height Z1. When a wire is held slack, the wire may form a curved shape similar to the first electrode **252** shown in Fig. 15A. The greater total length of the curved electrode **252** translates to a larger surface area than the wire-shaped electrode **232**. Thus, the electrode **252** will generate and emit more ions than the electrode **232**. Ions emitted by the first electrode array attach to the particulate matter within the airflow. The charged particulate matter is attracted to, and collected by, the oppositely charged second collector electrodes **242**. Since the electrodes **252** generate and emit more ions than the previously described rod or wire shaped electrodes **232**, more particulate matter will be removed from the airflow.

[0150] Fig. 15B illustrates that the first array of electrodes **230** may include flat coil wire-shaped electrodes **254**. Each flat coil wire-shaped electrode **254** also has a larger surface area than the previously disclosed wire-shaped electrode **232**. By way of example only, and in a preferred embodiment, if the electrode **254** was straightened out, the electrode **254** will have a total length that is preferably 10% longer than the rod shaped electrode **232**. Since the height of the electrode **254** remains at Z1, the electrode **254** has a "kinked" configuration as shown in Fig. 15B. This greater length translates to a larger surface area of the electrode **254** than the surface area of the electrode **232**. Accordingly, the electrode **254** will generate and emit a greater number of ions than electrode **232**. It is to be understood that an alternative embodiment of Fig. 15B can exclude the focus electrodes and be within the spirit and scope of the invention.

[0151] Fig. 15C illustrates that the first array of electrodes **230** may also include coiled wire-shaped electrodes **256**. Again, the height Z1 of the electrodes **256** are similar to the height Z1 of the previously described rod shaped electrodes **232**. However, the total length of each electrode **256** is greater than the total length of the rod-shaped electrodes **232**. By way of example only, and in a preferred embodiment, if the coiled electrode **256** was straightened out, each electrode **256** will have a total length two to three times longer than the wire-shaped

electrodes **232**. Thus, the electrodes **256** have a larger surface area than the electrodes **232**, and generate and emit more ions than the first electrodes **232**.The diameter of the wire that is coiled to produce the electrode **256** is similar to the diameter of the electrode **232**. The diameter of the electrode **256** itself is preferably 1-3mm, but can be smaller in accordance with the diameter of first emitter electrode **232**. The diameter of the electrode **256** shall remain small enough so that the electrode **256** has a high emissivity and is an ion emitting surface. It is to be understood that an alternative embodiment of Fig. 15C can exclude the focus electrodes and be within the spirit and scope of the invention.

[0152] The electrodes **252, 254** and **256** shown in Figs. 15A-15C may be incorporated into any of the electrode assembly **220** configurations previously disclosed in this application.

[0153] The foregoing description of the preferred embodiments of the present invention has been provided for the purposes of illustration and description. It is not intended to be exhaustive or to limit the invention to the precise forms disclosed. Many modifications and variations will be apparent to the practitioner skilled in the art. Modifications and variations may be made to the disclosed embodiments without departing from the subject and spirit of the invention as defined by the following claims. Embodiments were chosen and described in order to best describe the principles of the invention and its practical application, thereby enabling others skilled in the art to understand the invention, the various embodiments and with various modifications that are suited to the particular use contemplated. It is intended that the scope of the invention be defined by the following claims and their equivalents.